

Claims

1 1. A variable optical attenuator comprising:
2 an input/output optical system to which are connected a
3 plurality of input optical fibers and a plurality of output optical
4 fibers and which has a plurality of input lenses for taking beams
5 having entered by way of said input optical fibers as input beams
6 and a plurality of output lenses for gathering output beams to
7 be coupled to said output optical fibers, to thereby couple said
8 output beams to said output optical fibers;
9 a birefringent device provided on an output side of said
10 input/output optical system;
11 a liquid crystal device capable of changing polarizing
12 states of said input beams exiting said birefringent device;
13 and
14 a reflection device which reflects beams passing through
15 said liquid-crystal device so that the beams return to said output
16 lens of said input/output optical system by way of said
17 liquid-crystal device and said birefringent device.

1 2. The variable optical attenuator according to claim 1,
2 wherein said input/output optical system, said birefringent
3 device, said liquid-crystal device, and said reflection device
4 are integrated together.

1 3. The variable optical attenuator according to claim 2,
2 wherein said input/output optical system comprises

3 a fiber array block, in which a plurality of said input
4 optical fibers are arranged and connected in the form of an array
5 and a plurality of said output optical fibers are arranged and
6 connected in the form of an array in the same direction as that
7 in which the input optical fibers are arranged; and

8 a lens array block, in which a plurality of said input
9 lenses are arranged in the form of an array in accordance with
10 the arrangement of said input optical fibers in said input array
11 fiber block and in which a plurality of said output lenses are
12 arranged in the form of an array in accordance with the arrangement
13 of said output optical fibers in said output array fiber block.

1 4. The variable optical attenuator according to claim 3,
2 wherein a pitch between said input optical fibers and a pitch
3 between said output optical fibers are set so as to become greater
4 than a pitch between said input lenses and a pitch between said
5 output lenses.

1 5. The variable optical attenuator according to claim 3,
2 wherein said input/output optical system has
3 a prism unit which is interposed between said fiber array
4 block and said lens array block and which reflects a portion
5 of incident light in a direction crossing the direction of an
6 optical axis; and
7 a light-receiving unit for monitoring input and output
8 light which receives the light reflected from said prism unit.

1 6. The variable optical attenuator according to claim 5,
2 wherein said light-receiving unit is formed from a photodiode
3 array, in which a plurality of photodiodes, each photodiode having
4 a P electrode on one surface thereof and an N electrode on the
5 other surface thereof, are arranged in an array pattern on a
6 conductive transparent substrate such that said other surfaces
7 come into contact with said transparent substrate; and wherein
8 a common terminal of said N electrodes of said respective
9 photodiodes are provided on said transparent substrate.

1 7. The variable optical attenuator according to claim 5,
2 wherein said light-receiving unit is formed from a photodiode
3 array, in which a plurality of photodiodes, each having a P
4 electrode on one surface thereof and an N electrode formed around
5 said P electrodes, are arranged in the form of an array on a
6 transparent substrate.

1 8. the variable optical attenuator according to claim 1,
2 wherein said input/output optical system comprises
3 a fiber array block, in which a plurality of said input
4 optical fibers are arranged and connected in the form of an array
5 and a plurality of said output optical fibers are arranged and
6 connected in the form of an array in the same direction as that
7 in which the input optical fibers are arranged; and
8 a lens array block, in which a plurality of said input
9 lenses are arranged in the form of an array in accordance with
10 the arrangement of said input optical fibers in said input array

11 fiber block and in which a plurality of said output lenses are
12 arranged in the form of an array in accordance with the arrangement
13 of said output optical fibers in said output array fiber block.

1 9. The variable optical attenuator according to claim 8,
2 wherein a pitch between said input optical fibers and said output
3 optical fibers is set so as to be greater than a pitch between
4 said input lenses and a pitch between said output lenses.

1 10. The variable optical attenuator according to claim 8,
2 wherein said input/output optical system has
3 a prism unit which is interposed between said fiber array
4 block and said lens array block and which reflects a portion
5 of incident light in a direction crossing the direction of an
6 optical axis; and
7 a light-receiving unit for monitoring input and output
8 light which receives the light reflected from said prism unit.

1 11. The variable optical attenuator according to claim 10,
2 wherein said light-receiving unit is formed from a photodiode
3 array, in which a plurality of photodiodes, each photodiode having
4 a P electrode on one surface thereof and an N electrode on the
5 other surface thereof, are arranged in an array pattern on a
6 conductive transparent substrate such that said other surfaces
7 come into contact with said transparent substrate; and wherein
8 a common terminal of said N electrodes of said respective
9 photodiodes is provided on said transparent substrate.

1 12. The variable optical attenuator according to claim 10,
2 wherein said light-receiving unit is formed from a photodiode
3 array, in which a plurality of photodiodes, each having a P
4 electrode on one surface thereof and an N electrode formed around
5 said P electrode, are arranged in the form of an array on a
6 transparent substrate.

1 13. The variable optical attenuator according to claim 1,
2 wherein said reflection device is formed from a coupler film
3 which permits transmission of a portion of the light exiting
4 the liquid-crystal device; and
5 an input light monitor light-receiving unit for receiving
6 the light having passed through said coupler film is provided
7 on the surface of said coupler film.

1 14. The variable optical attenuator according to claim 13,
2 wherein said light-receiving unit is formed from a photodiode
3 array, in which a plurality of photodiodes, each photodiode having
4 a P electrode on one surface thereof and an N electrode on the
5 other surface thereof, are arranged in an array pattern on a
6 conductive transparent substrate such that said other surfaces
7 come into contact with said transparent substrate; and wherein
8 a common terminal of said N electrodes of said respective
9 photodiodes is provided on said transparent substrate.

1 15. The variable optical attenuator according to claim 13,

2 wherein said light-receiving unit is formed from a photodiode
3 array, in which a plurality of photodiodes, each having a P
4 electrode on one surface thereof and an N electrode formed around
5 said P electrode, are arranged in the form of an array on a
6 transparent substrate.

1 16. The variable optical attenuator according to claim 1,
2 wherein said input/output optical system is provided with an
3 output light monitor light-receiving unit for receiving the light
4 that is not coupled to said output optical fiber as a result
5 of a variation in the polarizing state of said liquid-crystal
6 device from among the beams reflected from said reflection device.

1 17. The variable optical attenuator according to claim 16,
2 wherein said light-receiving unit is formed from a photodiode
3 array, in which a plurality of photodiodes, each photodiode having
4 a P electrode on one surface thereof and an N electrode on the
5 other surface thereof, are arranged in an array pattern on a
6 conductive transparent substrate such that said other surfaces
7 come into contact with said transparent substrate; and wherein
8 a common terminal of said N electrodes of said respective
9 photodiodes is provided on said transparent substrate.

1 18. The variable optical attenuator according to claim 12,
2 wherein said light-receiving unit is formed from a photodiode
3 array, in which a plurality of photodiodes, each having a P
4 electrode on one surface thereof and an N electrode formed around

5 said P electrode, are arranged in the form of an array on a
6 transparent substrate.

1 19. The variable optical attenuator according to claim 1,
2 wherein said liquid-crystal device has a plurality of sets, each
3 set comprising liquid crystal and electrodes to be used for
4 applying an electric field to said liquid crystal, for controlling
5 a polarizing state of said liquid-crystal device for each beam
6 exiting said input optical fibers.

1 20. The variable optical attenuator according to claim 1,
2 wherein said liquid-crystal device has a plurality of sets, each
3 set comprising liquid crystal and electrodes to be used for
4 applying an electric field to said liquid crystal, for controlling
5 polarizing states of the liquid-crystal device for different
6 respective polarizing components of said input light separated
7 by said birefringent device.

1 21. The variable optical attenuator according to claim 1,
2 wherein said liquid-crystal device is formed from liquid-crystal
3 molecules and glass plates to be used for sandwiching said
4 liquid-crystal molecules, and said reflection device is formed
5 on the surface of one of said glass plates.

1 22. A variable optical attenuator comprising:
2 an input optical system to which a plurality of input optical
3 fibers are connected and which has a plurality of input lenses

4 that take beams exiting said input optical fibers as input beams;
5 a first birefringent device provided on an output side
6 of said input optical system;
7 a liquid-crystal device capable of varying the polarizing
8 states of respective input beams exiting said first birefringent
9 device;
10 a second birefringent device provided on an output side
11 of said liquid-crystal device; and
12 an output optical system to which a plurality of output
13 optical fibers are connected and which has a plurality of output
14 lenses for gathering output light exiting said second
15 birefringent device and coupling the gathered output light to
16 a corresponding output optical fiber.

1 23. The variable optical attenuator according to claim 22,
2 wherein said input optical system, said first liquid-crystal
3 device, said liquid-crystal device, said second birefringent
4 device, and said output optical system are integrated together.

1 24. The variable optical attenuator according to claim 23,
2 wherein said input optical system comprises
3 an input fiber array block in which a plurality of said
4 input optical fibers are arranged and connected in the form of
5 an array; and an input lens array block in which a plurality
6 of said input lenses are arranged in the form of an array according
7 to the arrangement of said input optical fibers provided in said
8 input fiber array block; and

9 wherein said output optical system comprises
10 an output fiber array block in which a plurality of said
11 output optical fibers are arranged and connected in the form
12 of an array; and an output lens array block in which a plurality
13 of said output lenses are arranged in the form of an array according
14 to the arrangement of said output optical fibers provided in
15 said output fiber array block.

1 25. The variable optical attenuator according to claim 22,
2 wherein said input optical system comprises
3 an input fiber array block in which a plurality of said
4 input optical fibers are arranged and connected in the form of
5 an array; and an input lens array block in which a plurality
6 of said input lenses are arranged in the form of an array according
7 to the arrangement of said input optical fibers provided in said
8 input fiber array block; and

9 wherein said output optical system comprises
10 an output fiber array block in which a plurality of said
11 output optical fibers are arranged and connected in the form
12 of an array; and an output lens array block in which a plurality
13 of said output lenses are arranged in the form of an array according
14 to the arrangement of said output optical fibers provided in
15 said output fiber array block.

1 26. The variable optical attenuator according to claim 22,
2 wherein said liquid-crystal device has a plurality of sets, each
3 set comprising liquid crystal and electrodes to be used for

4 applying an electric field to said liquid crystal, for controlling
5 a polarizing state of light exiting from said input optical fibers
6 on a per-beam basis.

1 27. The variable optical attenuator according to claim
2 22, wherein said liquid-crystal device has a plurality of sets,
3 each set comprising liquid crystal and electrodes to be used
4 for applying an electric field to said liquid crystal, for
5 controlling polarizing states of different polarizing components
6 of said input light separated by said first birefringent device
7 on a per-polarizing-component basis.